Weed Seedling Emergence and Survival as Affected by Crop Canopy

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This study measured impact of cool-season crops on seedling emergence, survival, and seed production of weeds common in corn and soybean. Weed dynamics were monitored in permanently marked quadrats in winter wheat, spring wheat, and canola. Three species, green foxtail, yellow foxtail, and common lambsquarters, comprised more than 80% of the weeds observed in the study. Seedling emergence was reduced by winter wheat, but not by spring wheat or canola, when compared with adjacent quadrats without a crop canopy. Approximately 10% of seedlings in spring wheat and canola developed into seed-bearing plants, but no seed-bearing plants were present in winter wheat at harvest. Common lambsquarters produced more than 1,100 seeds/plant, whereas a foxtail plant produced 85 seeds, averaged across spring wheat and canola. At harvest, new seedlings were present in all crops; thus, control after harvest will be required to prevent seed production in the fall. Winter wheat may provide an opportunity to disrupt population dynamics of weeds common in corn and soybean without requiring herbicides.

Nomenclature: Common lambsquarters, *Chenopodium album* L.; green foxtail, *Setaria viridis* (L.) Beauv.; yellow foxtail, *Setaria glauca* (L.) Beauv.; canola, *Brassica napus* L.; corn, *Zea mays* L.; soybean, *Glycine max* (L.) Merr.; wheat, *Triticum aestivum* L.

Key words: Population dynamics, seed-bearing plants, weed seed production.

Producers in eastern South Dakota can effectively control weeds in the corn–soybean rotation with a range of herbicides. However, resistant weeds (Heap 2007), rising input costs (Gibson et al. 2006), and concerns about human health and the environment (Kropff and Walter 2000) are stimulating producers to question the heavy reliance on herbicides for weed management.

One alternative to herbicide-centered management is to expand management to include strategies that disrupt population growth of the weed community (Anderson 2007; Mortensen et al. 2000). Our interest in this approach is based on a weed management program used in the semiarid Great Plains where cultural tactics decrease number of weed seeds in soil, reduce weed seedling establishment, and minimize seed production of plants that escaped control tactics (Anderson 2005). This approach has reduced weed community density across time such that producers manage weeds with 50% less cost compared with the conventional herbicide-centered system (Anderson 2008c). Herbicides are not needed with some crops because weed density is so low that crop yield is not affected by weeds.

A key component of this program in the semiarid Great Plains is rotations that include both cool-season crops such as winter wheat and warm-season crops such as corn (Anderson 2004). With different planting and harvest dates among these crops, producers can prevent either plant establishment or seed production by weeds with contrasting life cycles to the crop grown. For example, green foxtail emerges between mid-May and late June when the winter wheat canopy is well developed. Seedlings often die because reduced light penetration within the wheat canopy can be lethal to seedlings (Lemerle et al. 1996). If seedlings survive in the wheat canopy, they can start flowering by late July. Producers, however, can easily control these seedlings before they flower and produce seeds because winter wheat is harvested in early July. Preventing weed seed production during the year of winter wheat accentuates the natural decline of weed seed density in soil across time, which leads to fewer seedlings emerging in following years (Anderson 2003; Sagar and Mortimer 1976).

In eastern South Dakota, cool-season crops such as spring wheat are occasionally added to the corn–soybean rotation (NASS 2007). Also, producers in this region are starting to grow winter wheat because of improved winter hardiness with new cultivars. Adding these crops to the corn–soybean rotation should help weed management, but we are concerned that the shorter growing season in eastern South Dakota may reduce impact of crops with different life cycles on weed dynamics. For example, winter wheat matures 30 d later in eastern South Dakota compared with the semiarid Great Plains (Anderson 2008a). With this later development, warm-season weeds such as green foxtail may establish and produce seeds in cool-season crops, thereby minimizing impact of life cycle diversity on the weed community population.

This experiment was conducted to evaluate weed seedling recruitment and development of seed-bearing plants in cool-season crops. Our broader goal is to understand aspects of weed population dynamics as affected by crop diversity, and subsequently, develop a population-centered approach to weed management for the western edge of the Corn Belt.

Materials and Methods

Site Characteristics. The study was established on a Barnes clay loam (Calcic Hapludoll) near Brookings, SD. The soil contains approximately 3% organic matter and soil pH ranges from 6.8 to 7.2. Average yearly precipitation (84-yr record) is 537 mm, with May and June receiving the highest rainfall. The study sites were established in soybean stubble that had been harvested for forage. Before the study, the cropping history of the sites was corn–soybean.

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Treatments and Study Design. Three cool-season crops, winter wheat, spring wheat, and canola, as well as soybean, were compared for impact on weed dynamics. Winter wheat, 'Jerry', was planted at 140 kg/ha on September 16, 2002 and September 15, 2003. Spring wheat, 'Russ', at 140 kg/ha and canola, 'Invigor 2573', at 8 kg/ha were planted April 3, 2003 and April 6, 2004. Soybean, 'Pioneer 91B91', was planted at 395,000 seeds/ha May 27, 2003 and May 28, 2004. All crops were planted in rows spaced 19 cm apart with a disk drill. A starter fertilizer was applied with the crop seed at the rate of 17 kg/ha N, 43 kg/ha P, and 16 kg/ha K. In mid-April, ammonium nitrate was broadcast at 125 kg/ha N for winter wheat and 95 kg/ha N for spring wheat and canola. The starter fertilizer for soybean was applied between the crop rows; no further N fertilizer was applied to soybean.

The experimental design was a randomized complete block design with four replications. Plot size was 3 m by 20 m. Weeds present at planting of winter wheat and soybean were controlled with glyphosate applied at 1 kg ae/ha; weeds were not present when canola or spring wheat were planted. Crops were established with no till, and the site had not been tilled during the 2 yr preceding the study.

Two sites for recording weed seedling emergence were established in each plot. Each site consisted of three 0.33-m^2 quadrats. The site was randomly located in the plot, with the three quadrats randomly arranged in a triangle (Figure 1). Two quadrats were used to record seedling emergence, one within the crop and one without a crop canopy. Crop seedlings in the quadrat without a canopy were removed by hand as they emerged. Weed seedling counts were recorded weekly from April 9 to August 1 of 2003 and 2004 for winter wheat, spring wheat, and canola, whereas seedling counts in soybean started on the day of planting and continued to August 1. Seedlings were pulled and removed after counting. The third quadrat was used to determine establishment of seed-bearing plants in the crop. In this quadrat, seedlings were left undisturbed during the growing season, and before the cool-season crops were harvested in early August, the number of plants with seed heads was recorded. Samples were also collected in soybean at this time. Density of seed-bearing plants was compared with the number of seedlings recorded in the adjacent quadrat with a crop canopy to determine percentage of seedlings that reproduced.

Weed infestation among the four crops was also assessed in two randomly placed 0.5-m^2 quadrats in each plot the day before cool-season crops were harvested in early August. All weeds, including plants without a seed head, were harvested to determine species, density, and fresh weight of weeds. Crop biomass was also harvested for fresh weight, and the component of the plant community composed of weeds was determined by dividing the weed community biomass by total plant biomass (crop plus weeds) and converting to a percentage. In addition, 10 seed-bearing plants of each weed species were randomly collected from each plot of the four crops to determine seed production per plant. These samples were stored at room temperature until samples were processed.

Statistical Analysis. Data were subjected to analysis of variance[1] and means separated with Fischer's Protected LSD at the 0.05 level of probability. Data collected at sites within a plot were averaged for a plot value before analysis. Analysis indicated that an interaction did not occur between treatments and years; therefore, treatment data were averaged across years.

Seasonal emergence for the weed community was characterized by averaging seedling density for each weekly census across cool-season crops and years; standard error of the means was calculated for each weekly census. Seasonal emergence patterns for prominent weed species were developed by converting seedling density per week for a specific species to a percentage of its seasonal emergence (April 9 to August 1) and averaged across cool-season crops. Emergence curves were developed by cubic spline interpolation.[2]

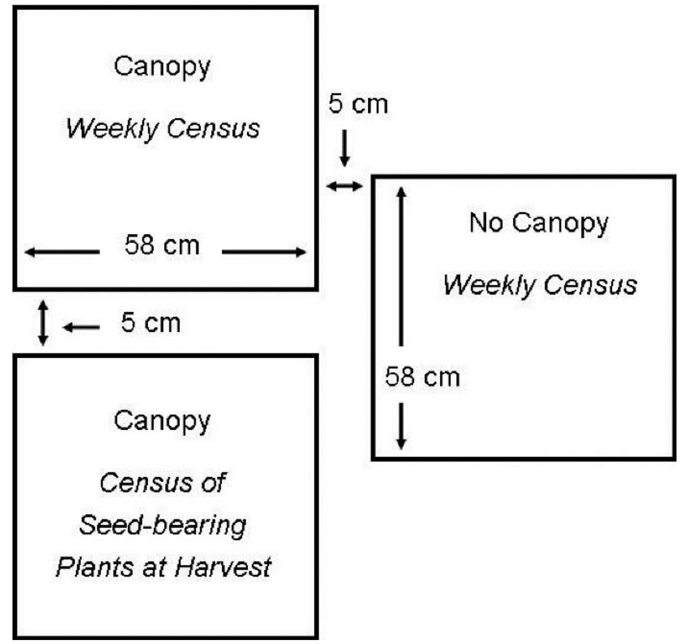

Figure 1. Alignment of three 0.33-m^2 quadrats for assessing seedling emergence and seed-bearing plants. Two sites were randomly located in each plot, and quadrats were randomly assigned at each site.

Results and Discussion

Weed Community. The prominent species observed in the study were green foxtail, yellow foxtail, common lambsquarters, redroot pigweed (*Amaranthus retroflexus* L.), common sunflower (*Helianthus annuus* L.), and yellow woodsorrel (*Oxalis stricta* L.). Seedling emergence was similar across years, beginning in early April and continuing until late July; more than 85% of the seedlings emerged between April 30 and June 18 (Figure 2). In both years, the two foxtail species and common lambsquarters comprised more that 80% of the total seedlings observed. Data for green and yellow foxtail were combined because of difficulty in distinguishing between seedlings of these species in the weekly census, and these species are referred to as the foxtail complex.

Seedling Recruitment and Establishment of Seed-Bearing Plants. Seedling emergence was approximately 44% less in

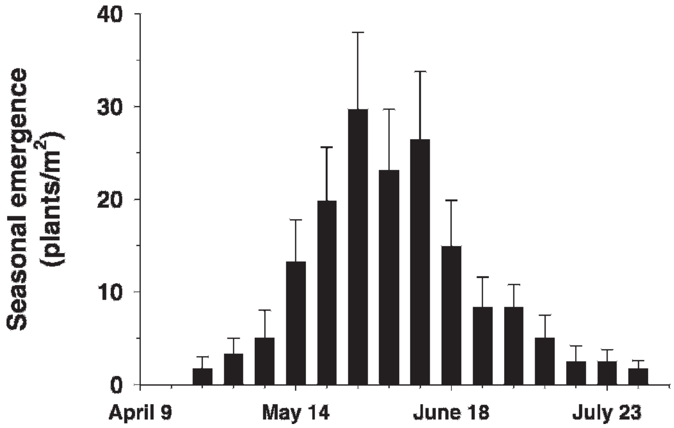

Figure 2. Seedling emergence of the weed community, averaged across crops and years. Standard error of the means for each weekly assessment is represented by the line with a cross-hatch above each bar.

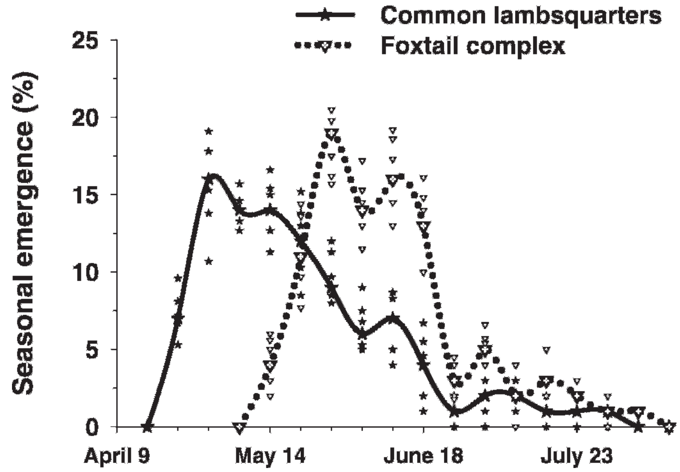

Figure 3. Seasonal emergence pattern for common lambsquarters and the foxtail complex (green and yellow foxtail). Data points represent yearly means for winter wheat, spring wheat, and canola at each census date.

winter wheat compared with spring wheat or canola (Table 1); seedling emergence did not differ among the cool-season crops with the no-canopy quadrats. The weed species most affected by winter wheat was the foxtail complex. This suppression of foxtail emergence began in late May. The first census in winter wheat where a difference occurred was May 21, when 41 seedlings emerged in the no-canopy treatment, contrasting with only 20 seedlings emerging in the canopy (data not shown).

Emergence of common lambsquarters, the other prominent species in the study, was not affected by winter wheat, which we attribute to its earlier emergence. Kruk et al. (2006) reported that wheat began suppressing weed seedling emergence 60 d after crop emergence. Common lambsquarters began emergence 2 to 3 wk before the foxtail complex, with most seedlings emerging in April and early May (Figure 3). This interval occurs 25 to 45 d after winter wheat initiates spring growth. Spring wheat, canola, or soybean did not affect seedling emergence of any species, which we attribute to later development of their crop canopies in relation to weed emergence.

Germination and emergence of weed seeds is a response to a complex interaction of several environmental factors, such as light intensity and quality, temperature amplitude, soil moisture, and concentrations of oxygen and carbon dioxide in soil (Egley 1986). Apparently, winter wheat altered this interaction among environmental factors to be less favorable for germination and seedling emergence of the foxtail species.

Even though winter wheat suppressed weed emergence, 87 seedlings/m^2 were still observed, including 51 foxtail plants (Table 1). Yet, no seed-bearing plants were present in winter wheat at harvest. In contrast, 7 to 11% of seedlings emerging in spring wheat or canola produced seeds by harvest. In soybean, 37% of emerged seedlings survived to produce seeds by August 1, similar to the rate of maturation reported in corn (Mohler and Callaway 1992).

Weed Seed Production by Established Plants. Foxtail plants produced 65 and 105 seeds/plant in spring wheat and canola, respectively, whereas individual plants produced 1,730 seeds in soybean (Table 2). Common lambsquarters produced approximately 1,200 seeds/plant in spring wheat or canola, or about one-third of its productivity in soybean. Spring wheat and canola suppressed productivity of the foxtail complex more than common lambsquarters because of the later emergence of the foxtail species (Figure 3).

The only other species in the weed community that developed seed-bearing plants was redroot pigweed. Plants of this species produced seeds in canola, but not in either winter

Table 1. Seedling emergence and plant establishment as influenced by crop. Data averaged across 2 yr.

	Seedling emergence			Seed-bearing plants		
Crop	No canopy	Canopy	Mature Plants[a]	Foxtail complex	Common lambsquarters	Redroot pigweed
	Plants/m^2		%	Plants/m^2		
Winter wheat	138 a[b]	87 b	0 c	0 c	0 b	0 b
Spring wheat	150 a	163 a	7 b	6.2 b	5.1 a	0 b
Canola	154 a	153 a	11 b	9.3 b	6.0 a	2.4 a
Soybean	70 b	65 b	37 a	17.9 a	3.4 a	3.1 a

[a] Percentage of mature plants was determined by comparing the number of seed-bearing plants at harvest to the number of seedlings recorded during the growing season in the adjacent weekly census quadrat with a canopy (see Figure 1).

[b] Means followed by an identical letter are not significantly different as determined by Fisher's Protected LSD ($P < 0.05$). Means for seedling emergence were compared both among crops and between canopy conditions with one LSD value because of a significant interaction between crop and canopy treatments. Means for seed-bearing plants were compared within columns.

Table 2. Seed production of weed species infesting spring wheat, canola, and soybean; no seed-bearing plants were observed in winter wheat. Data averaged across 2 yr.

Crop	Foxtail complex	Common lambsquarters	Redroot pigweed
	Seeds/plant		
Spring wheat	65 b[a]	1,210 b	0 c
Canola	105 b	1,140 b	15 b
Soybean	1,730 a	3,390 a	280 a

[a] Means within a column followed by an identical letter are not significantly different as determined by Fisher's Protected LSD ($P < 0.05$).

or spring wheat. Redroot pigweed seedlings began emerging the last week in May in both years and continued until August 1 (data not shown). Environmental conditions in the wheat canopies apparently differed from canola such that redroot pigweed seedlings were not able to survive in the former crops. Redroot pigweed in canola was approximately 25 cm tall at harvest and produced 15 seeds/plant; redroot pigweed produced 280 seeds/plant in soybean (Table 2).

Weed Community Density at Harvest. Weeds were present in all cool-season crops at harvest, including winter wheat (Table 3). Approximately 20% of foxtail complex and common lambsquarters plants observed in spring wheat and canola were new seedlings (data not shown), whereas all weeds present in winter wheat were seedlings. Postharvest control of these seedlings will be necessary to prevent weed seed production later in the growing season.

The component of the plant community biomass composed of weeds in spring wheat and canola was approximately 80-fold greater compared with winter wheat (Table 3). This difference in weed growth reflects establishment of some plants early in the growing season with spring wheat and canola, contrasting with only late-season seedlings present in winter wheat. Weeds made up more than half of the plant community biomass in soybean.

An intriguing trend occurred with yellow woodsorrel, as this species was present only in winter or spring wheat in early August. Yellow woodsorrel began emerging in late May in all crops, but seedlings present at harvest likely emerged in July because these plants had fewer than three leaves. Seedlings of yellow woodsorrel that emerged earlier in May and June did not survive in any crop. We were surprised that yellow woodsorrel seedlings were not present in soybean in early August; yellow woodsorrel occurs in the corn–soybean rotation in Ontario (Doust et al. 1985), and is invading no-till cropping systems in eastern South Dakota that include spring wheat in rotation with corn and soybean (Anderson 2008b). Yellow woodsorrel can flower 4 wk after emergence; we speculate that late-season establishment by this species in spring wheat may be an entry point for yellow woodsorrel invading no-till rotations. Once established as a perennial, yellow woodsorrel may more readily infest corn and soybean.

Implications for Weed Management. Our concern with delayed winter wheat development and its interaction with weeds common in corn and soybean was not valid; common lambsquarters and the foxtail complex did not produce seeds in winter wheat. Without seed production, the natural decline of weed seed density in soil across time will reduce density of weeds in following years. However, herbicides will be needed to prevent seed production of warm-season weeds that establish in spring wheat or canola. Winter wheat may provide an opportunity to disrupt population dynamics of weeds common in corn and soybean without requiring herbicides in the crop.

Producers will gain additional benefits by adding winter wheat to the corn–soybean rotation. Densities of soybean cyst nematode (*Heterodera glycines* Ichinohe) and corn rootworm (*Diabrotica* spp.) are reduced by more diverse rotations (Levine et al. 2002; Miller et al. 2006), and crop diversity can increase grain yield of corn and soybean (Dick and Van Doren 1985) and improve soil health (Zhang et al. 1996). However, producers may need to consider rotations with more crop diversity and a longer time frame to accentuate the benefits of winter wheat and other cool-season crops on weed management. Producers in the semiarid Great Plains following a population-centered approach to weed management have found that rotations that include two cool-season crops followed by two warm-season crops are the most favorable for reducing weed community density across time (Anderson 2007, 2008c).

Sources of Materials

[1] Statistix. Analytical Software. P.O. Box 12185, Tallahassee, FL 32317.

[2] Sigma Plot. Jandel Scientific, Point Richmond, CA 94804.

Table 3. Weed density in four crops and weed component of the plant community, with samples harvested in early August. Data averaged across 2 yr.

Crop	Weed species: Foxtail complex	Common lambsquarters	Redroot pigweed	Common sunflower	Yellow woodsorrel	Other[a]	Weed component of total biomass
	Plants/m^2						%
Winter wheat	2.5 c[b]	2.3 b	1.5 a	0 b	6.5 a	0.2 a	0.1 c
Spring wheat	6.3 b	9.5 a	0.5 a	1.8 a	9.3 a	1.3 a	8 b
Canola	12.7 b	8.1 a	1.5 a	1.6 a	0 a	1.5 a	9 b
Soybean	19.7 a	2.5 b	2.3 a	2.5 a	0 a	0.2 a	59 a

[a] Other weed species included buffalobur (*Solanum rostratum* Dun.), spotted spurge (*Euphorbia maculate* L.), and witchgrass (*Panicum capillare* L.).

[b] Means within a column followed by an identical letter are not significantly different as determined by Fisher's Protected LSD ($P < 0.05$).

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